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(54) Static inverter

(57) The inverter converts a D.C. supply to an A.C. supply and is particularly adapted for use to act as a standby electrical A.C. supply in the case of interruption of mains A.C. supply.

The A.C. supply is generated by the

inverter to have a square wave form with the desired peak voltage and frequency. The relationship between peak voltage ( $V_{pk}$ ) and the RMS voltage  $V_{rms}$  is  $V_{pk} = \sqrt{2}V_{rms}$ .

The inverter includes two inverter means 17, 18 each generating a square wave form A.C. output which are superimposed on one another additively. The length of three consecutive cycles of the wave form of one inverter means is the same as the length of one cycle of the other wave form. The peak voltage of one inverter means is added to the peak voltage of the other inverter means to provide the peak voltage of the resultant A.C. supply.

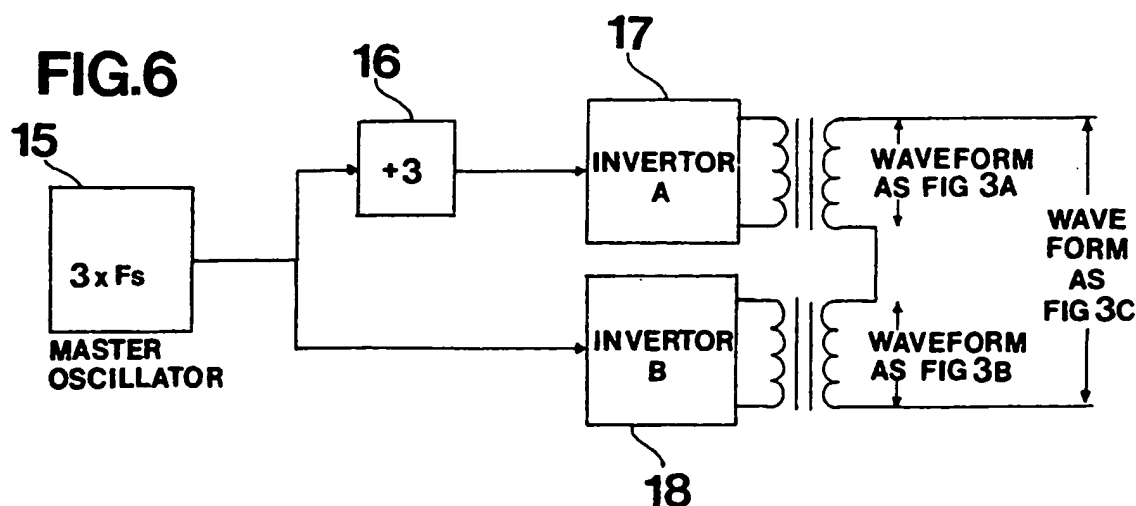
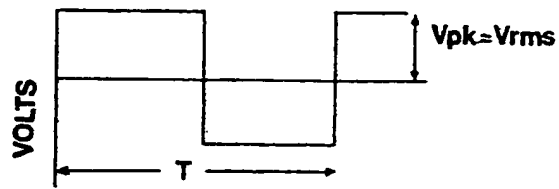


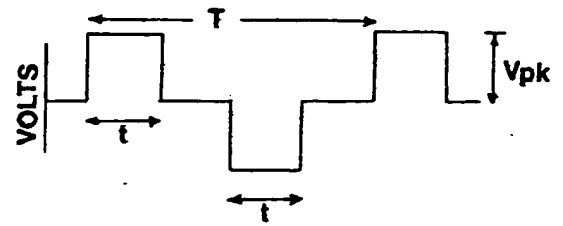
FIG.1

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FIG.2



OUTPUT VOLTAGE WAVEFORM



OUTPUT VOLTAGE WAVEFORM

FIG.3

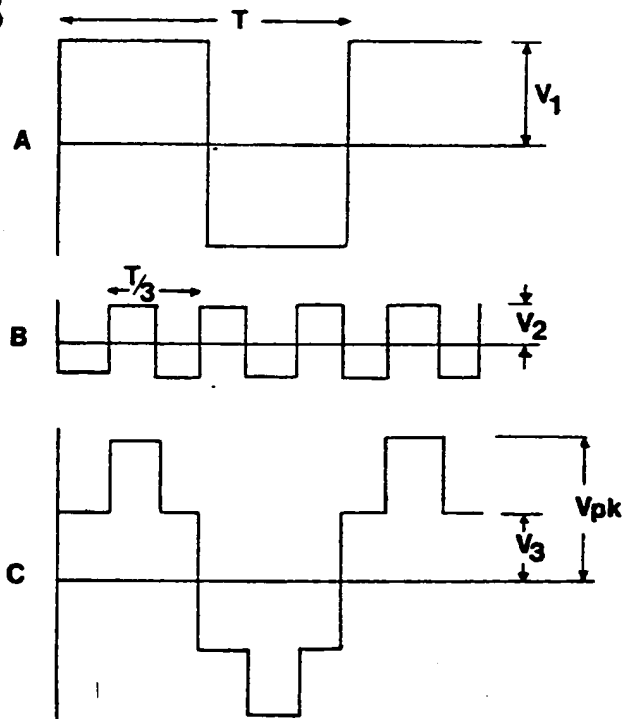


FIG.4

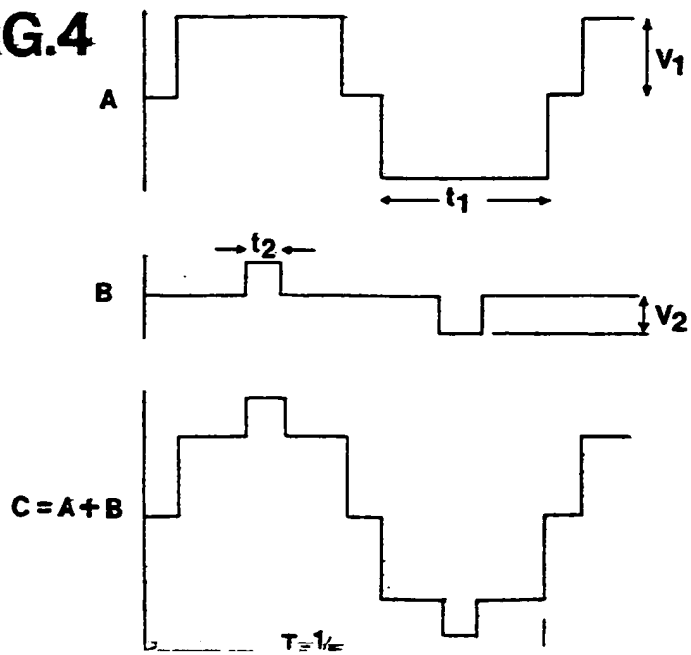


FIG.5

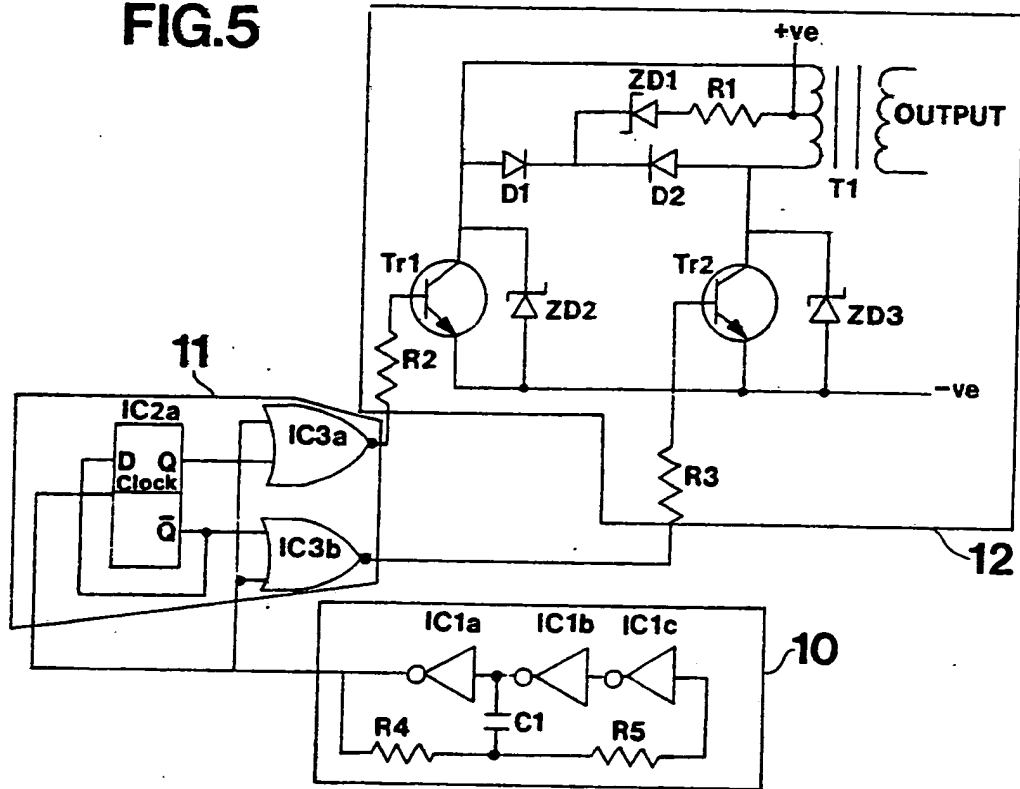
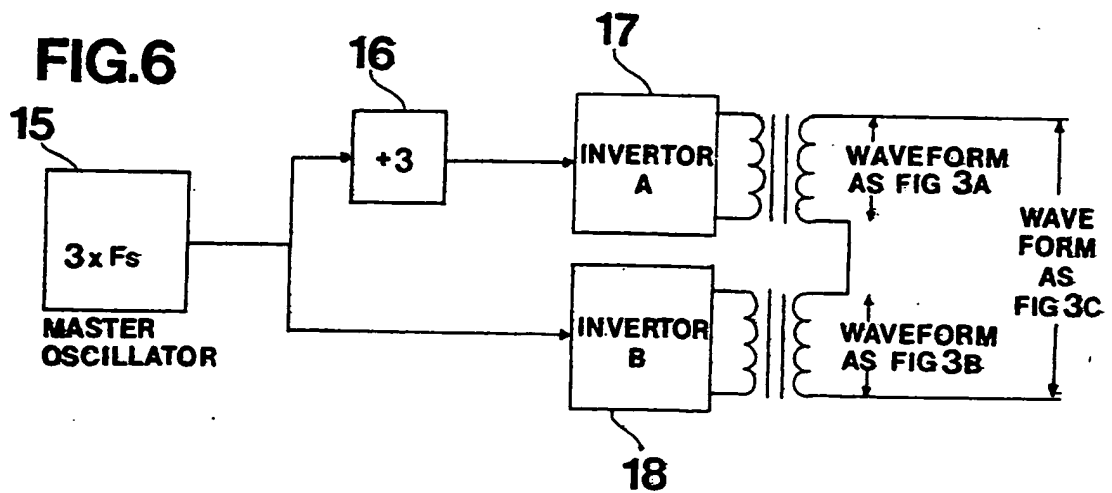


FIG.6



## SPECIFICATION

## Static inverter

5 This invention relates to static invertors and in particular to static invertors of the kind used in a standby supply for powering electrical equipment, which is normally supplied by the standard mains A.C. power supply, from a D.C. supply in the event  
10 that the mains power supply is interrupted or fails.

Static invertors are used to derive an A.C. supply from a D.C. supply, usually derived from batteries, when the mains supply fails. In order to derive an A.C. supply from a D.C. source in such circumst-  
15 ances it is desirable that the resultant A.C. supply has at least some of the characteristics of the original A.C. supply if the electrical equipment so supplied is to operate effectively, efficiently, or at all.

In the case of the original mains A.C. supply the  
20 supply can be defined by certain characteristics viz. voltage, frequency and waveshape. The voltage is usually defined as RMS voltage. The mains supply frequency is usually 50 or 60 Hz but other frequencies may be used. For mains supply the wave shape  
25 is always a sine wave.

The wave shape defines the different voltages involved.

Thus for a sine wave form

$$V_{pk} = \sqrt{2} V_{rms}$$

30 where  $V_{pk}$  is peak voltage and  $V_{rms}$  is the RMS voltage.

The form factor of the wave shape of a sine wave is 1.11 which is defined by

$\frac{V_{rms}}{V_{av}}$ ,  $V_{av}$  being the half cycle average voltage.  
35  $V_{av}$

These different voltages  $V_{pk}$ ,  $V_{rms}$  and  $V_{av}$  are relevant to the supply of different items of electrical equipment. For example when power is calculated the RMS value is used so heaters, lamps etc. require  
40 the correct RMS voltage to operate at the stipulated power rating. Electronic equipment converts the A.C. supply to D.C. by rectification and the rectifier requires the correct peak voltage. For some motors the average voltage is relevant. In the normal mains  
45 supply the relationship between the three voltages is fixed so the different requirements are met.

When the mains supply fails, normally mains driven equipment may be supplied from a D.C. supply provided by batteries by using an inverter  
50 which converts the low voltage D.C. supply into a high voltage A.C. supply. It has been proposed to provide invertors giving a square or rectangular wave form such as shown in Fig. 1 of the accompanying drawings and such invertors are relatively  
55 cheap and efficient. However in some applications problems arise due to the square wave shape of the supply. In square wave form  $V_{pk} = V_{rms} = V_{av}$ . In some cases, provided the correct voltage is used, the electrical equipment supplied will work with a  
60 square wave form inverter but this is not the case where, for example, two types of load are connected to the same supply, such as when a cooling fan

motor is on the same supply as electronic equipment. Moreover some such electrical equipment will  
65 not operate at all when supplied with the square wave supply of Fig. 1, for example synchronous motors often will not run and other motors may only run in a noisy manner.

It is possible to have invertors which provide a  
70 sine wave form but these are generally complicated and expensive and they tend to be less efficient than square wave forms.

An object of the invention is to provide a static inverter which can provide an A.C. supply from a  
75 D.C. source which supply is of a form compatible, in operating equipment, with the normal mains A.C. supply and which is relatively inexpensive.

Accordingly the invention provides a static inverter for converting a D.C. supply to an A.C. supply to  
80 act as the electrical supply in the case of interruption of mains A.C. supply, wherein the A.C. supply generated by the inverter has a square wave form having the desired peak voltage and frequency and the relationship between the peak voltage ( $V_{pk}$ ) and the RMS voltage ( $V_{rms}$ ) is generally  $V_{pk} = \sqrt{2} V_{rms}$ .

Conveniently the inverter generates a square wave form of reduced pulse width.

Preferably the wave form generated by the inverter comprises at least two superimposed, different  
90 square wave forms having a relationship such that the form factor of the resultant square wave form approximates to that of a corresponding sine wave form and is in the range 1.00 to 1.20.

Conveniently the inverter may include two inverter means each generating a square wave form  
95 which are superimposed on one another additively, the wave form of one inverter means being of three times the frequency of the other and having a peak voltage ( $V_2$ ) which is added to the peak voltage ( $V_1$ )  
100 of the other inverter means to provide the peak voltage ( $V_{pk}$ ) of resultant A.C. supply, the relationship of peak voltage ( $V_2$ ) of said one inverter means to the resultant supply peak voltage ( $V_{pk}$ )

being such that  $V_2 = \frac{V_{pk}}{4}$ ; and the relationship of

105 peak voltage ( $V_1$ ) of said other inverter means to the resultant supply peak voltage ( $V_{pk}$ ) being such that

$$V_1 = \frac{3V_{pk}}{4}.$$

According to another aspect the invention provides a static inverter comprising a D.C. electrical  
110 supply source, an oscillator, inverter means connected to the oscillator to generate from the oscillator output an A.C. electrical output of square wave form having a predetermined peak voltage and frequency and the wave form being such that the  
115 relationship between its peak voltage ( $V_{pk}$ ) and its RMS voltage ( $V_{rms}$ ) is  $V_{pk} = \sqrt{2} V_{rms}$ , and electrically powered equipment operable by the output supplied by the inverter means and by standard A.C. mains supply.

120 Preferably the inverter means generates two superimposed, different square wave forms one of the

wave forms being of higher frequency and lower voltage than the other wave form and being selected so that the form factor of the resultant square wave form approximates to that of a sine wave form of corresponding peak voltage and frequency.

Further features of the invention will appear from the following description of various embodiments of the invention and of the prior art, given by way of example only and with reference to the drawings in which:—

Fig. 1 shows the square wave form of a known inverter used for providing an A.C. supply from a D.C. source for operating equipment normally operated from a standard A.C. mains supply.

Fig. 2 shows the wave form of an inverter according to the invention,

Fig. 3 shows in A and B two individual square wave forms generated by a further inverter according to the invention and superimposed to give the wave form of C,

Fig. 4 shows in A and B the individual square wave forms generated by a still further inverter according to the invention, to give the wave form of C,

Fig. 5 shows a circuit diagram of an inverter for producing the wave form shown in Fig. 2, and

Fig. 6 shows a block diagram of an inverter for producing the wave forms of Figs. 3 and 4.

Referring to the drawings, Fig. 1 shows the wave form of a known square wave inverter which has been used to generate an A.C. output from a D.C. source in supplying electrical equipment when the normal mains A.C. supply fails. As already mentioned the wave form is of a simple square or rectangular shape. To match, as far as possible, this wave form with the mains supply characteristics, the voltage and frequency are controlled according to the mains frequency and voltage but in this case  $V_{pk}=V_{rms}=V_{av}$  which does not match the equivalent voltages of the mains supply. However by adjusting T the frequency can be related to the

supply frequency,  $F_s$ :—  $T = \frac{1}{F_s}$ .

Fig. 2 shows a wave form, which in common with that of Fig. 1, is a square or rectangular wave form but, in this case the wave form is of reduced pulse width. If the width t of the pulses is suitably adjusted by known means, in relation to the width T of a complete wave cycle, the characteristics of the wave form can be more accurately matched with the sine wave form of the mains supply which is to be substituted.

Thus if

$$T = \frac{4t}{V_{pk}^2}$$

$$V_{rms} = \sqrt{\frac{V_{pk}^2}{2}}$$

$$\text{and } V_{pk} = \sqrt{2} V_{rms}$$

and the relationship of  $V_{pk}$  to  $V_{rms}$  may be the same as the equivalent voltages in the mains A.C. supply, provided the peak voltage is also matched with the mains supply peak voltage. However the half cycle average voltage in this wave form does not match the equivalent voltage of a sine wave mains supply and the form factor of the wave form is 1.41 and above the sine wave form factor of 1.11. Accordingly

there are some items of equipment, such as motors, which are not satisfactorily operated with the A.C. supply from such an inverter but the inverter is more satisfactory than the inverter producing the wave form of Fig. 1 and is still a relatively cheap inverter.

To produce the wave form of Fig. 2 an inverter having the circuit shown in Fig. 5 may be used. An oscillator 10 generates a signal from a D.C. source and the signal passes to a steering circuit 11 in which it is divided into two signals of which each is passed to a different part of inverter means 12 which is arranged to produce an output signal of the form indicated in Fig. 2.

Referring now to Fig. 3, as an improvement on the wave form of Fig. 2 the inverter can be arranged to produce a square wave form such as shown in Fig. 3C. This wave form is derived from two square wave forms 3A and 3B superimposed on one another additively, the wave form 3A having a lower frequency and higher peak voltage than the wave form 3B.

In the resultant wave form of Fig. 3C

$$V_{pk} = V_1 + V_2$$

$$V_3 = V_1 - V_2$$

By suitable selection of the peak voltages  $V_1$  and  $V_2$  and the relative frequencies (the frequency of wave form of Fig. 3B is three times that of the wave form of Fig. 3A) it can be arranged that the RMS voltage to peak voltage ratio is as for a sine wave. Thus

$$V_{rms} = \sqrt{\frac{V_{pk}^2}{3} + \frac{2}{3} V_3^2}$$

$$\text{and } V_{rms} = \frac{V_{pk}}{\sqrt{2}}$$

$$\therefore \frac{2V_3^2}{3} = \frac{V_{pk}^2}{2} - \frac{V_{pk}^2}{3}$$

$$\text{So } V_{pk} = 2V_3$$

$$\therefore V_2 = \frac{V_{pk}}{4}$$

$$\text{and } V_1 = \frac{3V_{pk}}{4}$$

By selecting the relationship as indicated the wave form of Fig. 3C gives a form factor of 1.05 which is close enough to the sine wave form factor of 1.11 for the resultant supply to be acceptable to most loads.

The block diagram of Fig. 6 shows an inverter which generates the wave form of Fig. 3C. The circuit of Fig. 6 includes an oscillator 15 which generates a signal having three times the frequency of the wave form 3C. The signal is split and one of the resultant signals is divided by three at 16 to feed an inverter means 17 which generates the wave form of Fig. 3A. The other of the signals is fed to an inverter means 18 to generate the wave form of Fig. 3B and the two wave forms are added together to provide an output wave form as shown in Fig. 3C.

As a further alternative the wave form may have the shape shown in Fig. 4C which results from adding the wave forms of Figs. 4A and 4B in a similar manner to that of Fig. 3 except that in this case the wave forms of Figs. 4A and 4B are of reduced pulse width i.e. they are each of a similar form to the wave form of Fig. 2 by the use of inverter means of similar form to that of Fig. 5.

As in the Fig. 3 embodiment the frequencies of the wave forms 4A and 4B are selected to give the

desired frequency and form of the resulting wave form of Fig. 4C. The peak voltages V1 and V2 are

similarly selected so that  $V_{rms} = \frac{V_{pk}}{\sqrt{2}}$  where Vpk is

the peak voltage of the wave form of Fig. 4C.

- 5 Moreover by suitable selection of V1, V2 and the lengths of pulses t1 and t2 it can be arranged that the

form factor  $\frac{V_{rms}}{V_{av}} = 1.11$  which is the same as the

sine wave form factor of the mains supply.

- 10 The form of inverter means to produce the wave forms of Fig. 4 will be evident to those skilled in the art and will be along the same lines as those described in relation to Figs. 5 and 6 of the drawings.

- Using the inverter means producing the wave form of Fig. 4C it can be arranged that one or both of  
15 the pulses of wave forms 4A and 4B can be controlled to compensate for changes in supply voltage of the D.C. source or changes in the load on the supply to thereby maintain a substantially constant voltage supply from the inverter. This can be  
20 achieved by, for example, changing the voltage of the wave form 4B according to changes in the voltage to or from the inverter by feed back from said changing voltage.

- Other aspects of the inverter can be altered while  
25 still obtaining the benefit of using inverter means producing square wave forms. Thus instead of having the pulse width of the constituent wave forms of Figs. 4A and 4B reduced it is possible to reduce the pulse width of only one of such wave  
30 forms.

- Moreover the wave form of Fig. 3B can be different from that shown while still obtaining a resultant wave form similar to that of Fig. 3C. Thus the relative lengths of the peak voltages of the positive and  
35 negative pulses of the wave form of Fig. 3B may be different while still ensuring that for three complete cycles of the wave form the length is equal to the length T of a cycle of the wave form of Fig. 3A. Such a modified wave form, added to the wave form of  
40 Fig. 3A, is readily produced by inverter means by those skilled in the art. An inverter using such a modified wave form is able to generate a resultant wave form which in some ways is preferable to that shown in Fig. 3C in which Vpk does not have the  
45 same value in relation to V3 as shown.

#### CLAIMS

1. A static inverter for converting a D.C. supply to an A.C. supply to act as the electrical supply in the case of interruption of mains A.C. supply, wherein  
50 the A.C. supply generated by the inverter has a square wave form having the desired peak voltage and frequency and the relationship between the peak voltage (Vpk) and the RMS voltage (Vrms) is generally  $V_{pk} = \sqrt{2} V_{rms}$ .

- 55 2. A static inverter according to claim 1 wherein the inverter generates a square wave form of reduced pulse width.

3. A static inverter according to claim 1 wherein the wave form generated by the inverter comprises  
60 at least two superimposed, different square wave forms having a relationship such that the form factor

of the resultant square wave form approximates to that of a corresponding sine wave form and is in the range 1.00 to 1.20.

- 65 4. A static inverter according to claim 3 wherein the inverter includes two inverter means each generating a square wave form which are superimposed on one another additively, the wave form of one inverter means being of three times the frequency of the other and having a peak voltage (V2) which is added to the peak voltage (V1) of the other  
70 inverter means to provide the peak voltage (Vpk) of the resultant A.C. supply, the relationship of peak voltage (V2) of said one inverter means to the resultant supply peak voltage (Vpk) being such that

$$V2 = \frac{V_{pk}}{4}; \text{ and the relationship of peak voltage (V1)}$$

of said other inverter means to the resultant supply peak voltage (Vpk) being such that  $V1 = \frac{3V_{pk}}{4}$ .

5. A static inverter according to claim 3 wherein  
80 at least one of the superimposed square wave forms is of reduced pulse width.

6. A static inverter according to claim 5 wherein two superimposed square wave forms are generated to be each of reduced pulse width the wave  
85 forms being arranged to have a form factor which approximates to that of a sine wave.

7. A static inverter according to claim 5 or 6 wherein the peak voltages of the individual wave forms (V1 and V2) and the frequency and duration of  
90 the pulses is arranged so that  $V1 + V2 = V_{pk}$  and the RMS voltage (Vrms) and the average voltage (Vav)

have a relationship such that  $\frac{V_{rms}}{V_{av}}$  is substantially

equal to the sine wave form factor.

8. A static inverter according to claim 6 or 7  
95 wherein the peak voltage (V1) of one wave form is substantially less than the peak voltage of the other wave form (V2) and in order to give a resultant peak voltage (Vpk) on the output supply under differing load and/or D.C. supply voltage a change in input/  
100 output voltage is detected and the lower peak voltage (V1) is adjusted to retain substantially the same output supply peak voltage (Vpk).

9. A static inverter comprising a D.C. electrical supply source, an oscillator, inverter means connected to the oscillator to generate from the oscillator output an A.C. electrical output of square wave form having a predetermined peak voltage and frequency and the wave form being such that the relationship between its peak voltage (Vpk) and its  
110 RMS voltage (Vrms) is  $V_{pk} = \sqrt{2} V_{rms}$ , and electrically powered equipment operable by the output supplied by the inverter means and by standard A.C. mains supply.

10. A static inverter according to claim 9 wherein  
115 the inverter means generates two superimposed, different square wave forms one of the wave forms being of higher frequency and lower voltage than the other wave form and being selected so that the form factor of the resultant square wave form  
120 approximates to that of a sine wave form of



corresponding peak voltage and frequency.

11. A static inverter substantially as described having the wave form substantially as shown in Fig. 3(C) of the drawings.

12. A static inverter substantially as described and having the circuit substantially as shown in Fig. 5 of the drawings.

13. A static inverter substantially as described and having the wave form substantially as shown in Fig. 4(C) of the drawings.

14. A static inverter substantially as described having the circuit substantially as shown in Fig. 6 of the drawings.

New claims or amendments to claims filed on 11 Jan. 1983.

Superseded claims 1-14.

1. A static inverter for converting a D.C. supply to an A.C. supply to act as the electrical supply in the case of interruption of mains A.C. supply wherein the A.C. supply generated by the inverter has a square wave form having the desired peak voltage and frequency and the relationship between the peak voltage ( $V_{pk}$ ) and the RMS voltage ( $V_{rms}$ ) is generally  $V_{pk} = \sqrt{2} V_{rms}$ , wherein the inverter includes two inverter means each generating a square wave form A.C. output which wave forms are superimposed on one another additively, the length of three consecutive cycles of the wave form of one inverter means being the same as the length of one cycle of the other wave form, the peak voltage ( $V_2$ ) of said one inverter means being added to the peak voltage ( $V_1$ ) of the other inverter means to provide the peak voltage ( $V_{pk}$ ) of the resultant A.C. supply, which has a form factor approximating to that of a sine wave form and lying in the range 1.00 to 1.20.

2. A static inverter according to claim 1 wherein the relationship of peak voltage ( $V_2$ ) of said one inverter means to the resultant supply peak voltage

( $V_{pk}$ ) being such that  $V_2 = \frac{V_{pk}}{4}$ ; and the relationship

of peak voltage ( $V_1$ ) of said other inverter means to the resultant supply peak voltage ( $V_{pk}$ ) being such

that  $V_1 = 3 \frac{V_{pk}}{4}$ .

3. A static inverter according to claim 2 wherein the relative lengths of the positive and negative peak voltages generated by said one inverter means are different while still ensuring that the length of three complete cycles of the generated wave form is equal to a complete cycle length of the wave form generated by said other inverter means.

4. A static inverter according to claim 6 or 7 wherein the peak voltage ( $V_1$ ) of one wave form is substantially less than the peak voltage of the other wave form ( $V_2$ ) and in order to give a resultant peak voltage ( $V_{pk}$ ) on the output supply under differing load and/or D.C. supply voltage a change in input/output voltage is detected and the lower peak voltage ( $V_1$ ) is adjusted to retain substantially the same output supply peak voltage ( $V_{pk}$ ).

5. A static inverter comprising a D.C. electrical

supply source, an oscillator inverter means connected to the oscillator to generate from the oscillator output an A.C. electrical output of square wave form having a predetermined peak voltage and frequency and the wave form being such that the relationship between its peak voltage ( $V_{pk}$ ) and its RMS voltage ( $V_{rms}$ ) is  $V_{pk} = \sqrt{2} V_{rms}$ , and electrically powered equipment operable by the output supplied by the inverter means and by the standard A.C. mains supply, wherein the inverter means generates two square wave form A.C. outputs, the length of a complete cycle of one of the wave forms being three times the length of three consecutive cycles of the other wave form, and the two wave forms being superimposed on one another additively so that the peak voltage of one wave form is added to the peak voltage of the other wave form to provide the peak voltage of the resultant A.C. supply which has a form factor approximating to that of a sine wave form.

6. A static inverter substantially as described having the wave form substantially as shown in Fig. 2(c) of the drawings.

7. A static inverter substantially as described having the circuit substantially as shown in Fig. 3 of the drawings.

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